Forest Practices on Non-Federal Lands and Pacific Salmon Conservation

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1.0 Purpose

The purpose of this paper is to provide guidance for biologists working on development or review of proposals for management of non-federal forest lands in Idaho, Oregon or Washington states. These proposals could involve habitat conservation plans, harvests on tribal lands, state forest practice rules, or individuals that wish their private lands harvest to be covered under ESA section 7 road use permits. The scientific information included in this document about functions and processes of forested landscapes, effects of forest practices on habitat processes and functions, and considerations for developing conservation measures also should prove valuable to biologists working on forest management proposals on Federal lands. For more information on Federal lands, refer to the online guidance for this subject.

2.0. Introduction

Habitat degradation has been associated with many of the documented extinctions or declines of anadromous and resident salmonid fishes in the Pacific Northwest (Nehlsen et al. 1991, FEMAT 1993, Henjum et al. 1994, Botkin et al. 1995, Independent Scientific Group 1996 and 2000, National Research Council 1996, Lee et al. 1997). Twenty-six populations of salmon and steelhead (Pacific salmon) are listed as threatened or endangered under the Federal Endangered Species Act (ESA) in Idaho, Oregon, Washington, and California. This paper provides guidance for review of state forest practice programs and for ESA consultations on non-federal forest management proposals *(e.g..*, tribal harvests), and also provides information that should be useful in the development and review of habitat conservation plans and other conservation agreements with non-federal landowners.

The effects of forest management are among the effects of land and water use over the past century that collectively have greatly altered the functioning and biological productivity of river basins in the Pacific Northwest (FEMAT 1993, Henjum et al. 1994, Wissmar et al. 1994, Botkin et al. 1995, Independent Scientific Group 1996 and 2000, National Research Council 1996, Lee et al. 1997).

NOAA's National Marine Fisheries Service (NOAA Fisheries) is involved with forest practices because it is responsible for protecting listed salmon and steelhead on all land ownerships, and because forest lands provide some of the best remaining habitat for anadromous fish populations. The ESA requires non-federal landowners only to avoid unauthorized "take" (killing or harming[4]) of listed species. NOAA Fisheries encourages additional protective measures on non-federal lands that will help ensure the long-term survival of listed species through habitat conservation planning and voluntary recovery efforts, while allowing forest landowners sufficient management options to discourage conversion of forest lands to other uses. NOAA Fisheries has cooperated with state-based Pacific salmon recovery efforts in Washington and Oregon.

On Federal forest lands, anadromous fish generally are relatively well-protected due to the Northwest Forest Plan (west of the Cascades crest) and the Pacfish strategy (east of the Cascades crest), but the distribution of Federal lands is not always optimal for the conservation of anadromous fish. In some areas, Federal lands are concentrated in the headwater areas of watersheds, and lower gradient river reaches that were historically important for certain species, such as coho salmon, have largely been developed to the detriment of these species. In other areas, Federal lands (particularly those owned by the Bureau of Land Management) are distributed in a checkerboard fashion, resulting in fragmented

[4]Sections 4(d) and 9 of the ESA prohibit any taking (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct) of listed species without a specific permit or exemption. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, and sheltering. Harass is defined as actions that create the likelihood of injuring listed species to such an extent as to significantly alter normal behavior patterns which would include, but are not limited to breeding, feeding, and sheltering.

landscapes that make it difficult to restore watershed functions and salmon habitat based solely on Federal land management.

Spence et al. (1996) discussed the need to consider ecological linkages across lands under multiple ownership:

> The success of salmonid populations depends on the availability of high-quality habitats needed during each life stage . . . A strategy for non-federal lands should build upon existing conservation plans by re-establishing connectivity between habitat on Federal and non-federal lands, and by working towards protection of habitats that are poorly represented in Federal ownership, particularly the lower-elevation streams and habitats for resident species, including nongame fishes.

The National Research Council (1996) noted the tension between the need to implement river-basin scale conservation and private property rights:

> . . . there is little doubt that over the last century land and water uses on many privately owned lands have continued to degrade in aquatic habitat and resulted in loss of the natural production capacity of these waters (Lichatowich 1989, Thomas et al. 1993, Moyle and Yoshiyama 1994). Uniform and consistently applied habitat-conservation strategies are not practiced on the scale of river basins, the scale most relevant to the metapopulation structure of Pacific salmon. The dilemma is clear. How can private property rights be respected while adequate habitat is provided for salmon across the landscape?

The Council described several elements of a possible solution to this dilemma:

> The committee believes that progress toward solving the dilemma is possible and recommends that attention be given to developing a *more equitable and more uniform system of habitat-protection requirements on private ownerships* across all land uses, establishing *joint planning groups* for entire river basins (or subbasins), where private landowners can participate in land-use policy decisions, investigating various *incentives* for landowners to practice improved environmental stewardship, and expanding programs that involve *the public* in monitoring and habitat-conservation projects. Those steps would benefit not only salmon but virtually all public values associated with aquatic-riparian ecosystems (emphasis as in original).

3.0. Functions and Processes of Forested Landscapes that Affect Pacific Salmon

3.1. Channel and Riparian Functions

Because of their proximity and connections to streams, ecological conditions and processes in riparian areas strongly influence aquatic habitats. Riparian areas provide: shade that mediates water temperature; cover for fish hiding, resting, and feeding; structural elements of stream channels; and substrate materials. Riparian vegetation supplies and processes nutrients; supports food webs; stabilizes streambanks; dissipates stream energy; filters and traps upland and flood-transported sediments; captures marine-derived nutrients from salmonid carcasses; and hydrologically links side channels, floodplains, and groundwater (Cederholm and Peterson 1985, Sullivan et al. 1987, Gregory et al. 1991, FEMAT 1993, Spence et al. 1996).

Most riparian area functions affecting streams and anadromous fish, including bank stability, shade, litterfall, LWM recruitment, occur within a distance equal to the height of a site-potential tree from the edge of the streambank (FEMAT 1993, Spence et al. 1996) for streams without a floodplain, and decline rapidly beyond that distance. Where there is a floodplain, riparian area functions may extend for a distance equal to the height of a site-potential tree from the edge of the floodplain, since during a flood the entire floodplain can function as the stream channel (Rhodes et al. 1994).

Microclimate functions are affected by activities in an area greater in width than what is commonly defined as the riparian area. Natural riparian microclimate extended at least 45 m (148 feet) from streams in a Douglas-fir and western hemlock forest, although some variables extended up to 300 m (984 feet) from streams (Brosofske et al. 1997).

The majority of litterfall, a source of nutrients to streams, is provided by vegetation within a distance equal to one-half to three-quarters of a site potential tree height (FEMAT 1993). Bank stability is affected by trees in the zone where roots can extend to the stream bank (Beschta 1991, Beschta and Platts 1991), up to approximately 30 feet from the stream for mature forests. Trees farther away from an existing stream bank can be important to future bank stability for streams with an active channel migration zone.

Large woody material (LWM) is an important component of freshwater salmonid habitat. LWM regulates sediment and flow routing, influences stream channel complexity and stability, increases pool volume and area, and provides hydraulic refugia and cover within streams (Bisson et al. 1987, Gregory et al. 1987, Carlson et al. 1990, Hicks et al. 1991b, Sedell and Beschta 1991, Ralph et al. 1994, Bilby and Bisson 1998). Large riparian trees are needed to provide the key pieces of large wood that are stable in stream channels, forming log jams and pools (Ralph et al. 1994, Abbe and Montgomery 1996, Beechie and Sibley 1997). Pieces as large as 24 to 79 inches in diameter may be needed for a large stream, based on the sizes of wood pieces anchoring valley-spanning log jams (Montgomery et al. 1996). Modeling by Meleason et al. (2003) indicated that maximum in-channel volume of wood for buffers of 30 m (98 feet) or greater required 500-year old forests. Even in small streams, large boles function differently than small boles, forming higher waterfalls and longer sediment terraces that enhance organic matter storage and nutrient cycling, ameliorate sediment routing to fish-bearing streams, and provide conditions that result in cooler subsurface stream flows (Bilby 1984).

LWM also plays a key role in retaining salmon carcasses (Cederholm and Peterson 1985), a major source of nitrogen and carbon in stream ecosystems (Bilby et al. 1996). Large wood in streams has been reduced through a variety of human activities that include past timber harvest practices and associated activities, as well as the mandated cleanup activities that removed wood from streams throughout the region from the 1950s through the 1970s (FEMAT 1993, Botkin et al. 1995, Bilby and Bisson 1998).

The biological and physical effects of riparian areas on streams vary with the position of the stream reach in the fluvial network. Headwater streams (including non-fish bearing streams) play an important role in watershed function by storing and routing sediment, and providing high quality water, LWM, organic litter, and dissolved nutrients into the lower gradient fish-bearing streams (Sullivan et al. 1987, Murphy 1995, Spence et al. 1996). LWM in headwater streams increases sediment retention by forming depositional areas and dissipating energy; retains non-woody organic matter, allowing it to be biologically processed prior to downstream export as dissolved and particulate nutrients; and delays surface water passage, allowing it to be cooled by mixing with ground water (Sullivan et al. 1987, Murphy 1995, Spence et al. 1996, Bisson and Bilby 1998). Intermittent or ephemeral streams may be important sources of sediment and large wood to perennial streams (see discussion under Upland Functions), and seasonally contribute to perennial stream flow.

3.2. Upland Forest Functions

Ecological conditions and processes in upland forests can affect surface erosion and mass wasting rates, the volume and timing of peak stream flows, and nutrient dynamics, and therefore need to be considered in determining effects of forest practices on fish habitat and water quality (Chamberlin et al. 1991, Spence et. al. 1996, IMST 1999). Effects of forest management on these functions is discussed in section 4.2 of this document.

Landslides that begin on hillslopes or headwalls can continue as debris flows that increase in volume as they move downstream. Such events can damage or destroy salmonid habitat by scouring streams to bedrock, or by depositing large amounts of sediment (Swanston 1991). Based on an investigation of three streams in the Oregon Coast Range, Reeves et al. (1995) concluded that under a natural disturbance regime, periodic inputs of coarse sediment (boulders, cobble and gravel) and large wood in landslides may help create productive salmonid habitat, as these materials can be depleted in stream channels over long periods of time. In some areas, wood transported in this manner may constitute one-half or more of the wood recruited to downstream reaches (McGarry 1994, May and Gresswell 2003). McDade et al. (1990) could not account for 48% of the existing LWM pieces in a study of recruitment from streamside areas in the Oregon Coast Range. Reeves et al. (2003) found approximately 65% of wood pieces and 46% of wood volume found within the bankfull channel and adjacent floodplain originated from upland sources more than 295 feet (90 m) from the stream channel.

The rate and composition of landslides (Reeves et al. 1995), channel gradient and tributary junction angle (Benda and Cundy 1990), and the presence of mature trees in runout zones that can reduce debris flow runout distance (Benda et al. 1997, Robison et al. 1999) are major factors determining effects of these events on fish habitat. Benda and Cundy (1990) predicted deposition where stream gradients decline to below 3.5° (~6%) or where stream junction angles are greater than 70°. Where deposition occurred in association with stream junction angle, deposition extended 164 to 492 feet (50 to 150 m) downstream. The volume and distance of debris torrents is inversely related to the quantity of wood contained in the torrent (Robison et al. 1999, Lancaster et al. 2001, Lancaster et al. 2003). Sediment in these unconsolidated depositions from debris flows can be mobilized in dam-break floods. In some instances a small dam-break flood may quickly develop into a large migrating organic dam, affecting stream habitat well downstream of the original event (Coho and Burges 1994).

3.3. Biological Functions

Beavers can have both positive and negative effects on water bodies and riparian ecosystems. Beaver feeding may reduce standing woody riparian vegetation, but also increases the input of wood to streams. Beaver ponds often fill with sediments and become wetlands, but they retard erosion upstream and reduce sedimentation downstream. The ponds supplement summer low flows and provide important low-velocity over-wintering habitat for salmonid fishes. Beaver ponds may also provide a sink for nutrients from tributary streams, enhancing pond productivity, and increasing retention. Overall, the reduction in beaver populations since European settlement has caused fundamental changes in ecosystem structure and function (Spence et al. 1996, Pollock et al. 2003). For example, Pollock et al. (2004) estimate that summer habitat capacity for coho salmon provided by ponds in the Stillaguamish River basin in Washington state has been reduced by 88% and that winter habitat capacity has been reduced by 93% over pre-settlement conditions. Where coho salmon production is limited by pool availability and where conditions are suitable, allowing or encouraging beaver to build dams may be more cost-effective and appropriate as a restoration technique than adding LWM (Pollock et al. 2004).

4.0. Effects of Forest Practices on Habitat Processes and Functions

4.1. Effects on Riparian and Channel Functions

4.1.1. Riparian Harvest and Salvage

Logging operations have the potential to adversely affect ecological functions and characteristics that shape aquatic habitat (Gregory et al. 1987, Chamberlin et al.1991, Murphy 1995). Timber harvest and salvage activities within a distance equal to one site-potential tree height of streams have the potential to change the distribution, size, and abundance of LWM that is recruited from adjacent riparian areas (Hicks et al. 1991, FEMAT 1993, Murphy 1995, Spence et al. 1996). However, because LWM recruitment potential declines rapidly moving away from the stream, a buffer of 100 feet includes about 80-98% of streamside LWM recruitment potential, depending on stand age and other factors (McDade et al. 1990, Van Sickle and Gregory 1990). Murphy (1995) compared riparian protection offered by forest practice rules in Idaho, Oregon, Washington and Alaska and noted that stream buffers on private lands generally are not wide enough to provide full long-term recruitment of LWM.

Since one-half or more of the wood in a stream can come from upslope and upstream areas through landslides and debris flows (see discussion in Section 3.2 above), timber harvest on unstable slopes and along debris flow runout paths likely reduces the potential recruitment of LWM to streams (Hicks et al. 1991a, Reeves et al. 1995, May and Gresswell 2003, Reeves et al. 2003).

State forest practice rules commonly allow partial harvest in at least part, and usually most, of the area within one site-potential tree height of stream channels. Modeling studies in western Washington indicate that riparian thinning increases LWM recruitment when trees in the initial stand are too small to create pools (LWM size required to create pools increases with increasing channel width) (Beechie et al. 2000). When trees in the initial stand already are large enough to form pools, thinning reduces the number of trees available for recruitment. For modeled Douglas fir stands, thinning increased LWM recruitment when channels were at least 15 m (49 feet) and the quadratic mean diameter of the stand was about 10 cm (3.9 inches) less than the minimum pool-forming diameter for the channel size. Recruitment was not enhanced by thinning for channels narrower than those described above. The above thinning results are based on rotations that are long enough to ensure that trees are not harvested before they attain the needed size to function in the channel, an assumption that likely is not valid in at least some states (Botkin et al. 1995, Murphy 1995). The shorter the rotation, and the wider the channel, the lower the percentage of riparian stands that will contribute functional LWM to the channel.

Alder forests generally do not persist beyond 100 years, and confers may be understocked after senescence of the stand. Some state forest practice rules allow or encourage conversion of alder stands to conifer. This presents both risks and opportunities to fish habitat needs. Hardwood conversions may allow removal of existing conifer trees, eliminating the possibility of near-term LWM recruitment, and may not adequately protect shade, increasing the risk of stream temperature increases. Modeling of red alder stands by Beechie et al (2000) in western Washington suggests that stands with a quadratic mean diameter at least 25 cm (9.8 inches) less than the minimum pool-forming diameter for the channel size could be thinned to introduce conifer gradually, without loss of near-term LWM recruitment, when channels were at least 20 m (66 feet) wide. In other red alder stands, thinning and planting with conifer would inhibit near-term recruitment of LWM, but was likely to increase long-term LWM recruitment from conifer.

Removal of riparian trees can reduce bank stability, thereby increasing sediment delivery (Sullivan et al. 1987, Gregory et al. 1991). Bank stability can be affected by removing trees in the zone where roots can extend to the stream bank (Beschta 1991) (up to approximately 30 feet from the stream for mature forests, or wider where there is a channel migration zone).

Buffer widths needed for filtration of sediment vary widely depending on site conditions. Buffer widths needed for sediment filtration may vary from 30-90 m (98-295 feet) or more depending on slope, parent rock type, and other factors (Spence et al. 1996 p. 219, FEMAT 1993 p. V-38). However, stream-side buffers are not effective in removing sediment carried in channelized flows (including intermittent streams) that originate outside of the buffer and continue through it (Fig. 1) (Belt et al. 1992).

Figure 1. Sediment-laden, channelized runoff flow in vicinity of Meadow Timber Sale, Panjab Creek watershed, Umatilla National Forest, 1993. Photo: Morris Owen, Washington Department of Wildlife.

Water temperature within a stream is a function of both external factors, such as solar radiation, air temperature, precipitation and flow, and internal factors such as width-to-depth ratios, groundwater inputs, and hyporheic exchange (Poole and Berman 2001). Forest management can affect both external factors (e.g. solar radiation to the stream can be increased by canopy and shade reduction) and internal factors (e.g. connectivity of streams with floodplains (Brown and Krygier 1970, Bisson et al. 1987, Bilby and Bisson 1998).

Stream shade can be affected by logging within a distance equal to approximately three-quarters of a site potential tree height (FEMAT 1993, Spence et al. 1996). For small streams in western Oregon, the riparian buffer width needed to provide 75-90% of angular canopy density varied widely, from 30-145 feet (Beschta et al. 1987). In microclimate studies in western Washington by Brosofske et al. (1997), stream water temperature was unaffected by buffer sizes of 12-72 m (39-236 ft) in width on streams that were 2-4 m (7-13 ft) wide with moderate to steep slopes, in a variety of valley formations and with various aspects. One stream without a buffer was warmer than the other streams. A study of the effects of harvest under Oregon forest practices rules (i.e. 20-foot no harvest with varying basal area retention for the next 30-80 feet from the stream) showed median shade levels for harvested sites were 6.5% to 21.5% lower than shade levels on “other” (not recently harvested) sites when stratified by stream size (large, medium, small) (Oregon Department of Forestry 2001). For each of the stratified stream size data sets, 70% to 100% of the “other” sites had shade levels that were higher than the median shade level of the harvested sites, even though basal areas in many of the harvested streams were higher than the minimum required to be left under the rules.

Following complete canopy removal in a 175-acre watershed in the Oregon Coast Range, mean monthly maximum temperature for July increased from 13.9° C (57° F) to 21.7° C (71° F), and the diurnal temperature range increased by 15° C (Brown and Krygier 1970). A review of the effects of riparian canopy removal on stream temperatures at the reach scale concluded that increases in average summer maximum temperatures of about 3 to 8° C are common (Beschta et al. 1987). Reduction in large wood recruitment, increased landslide rates and sediment yield, more efficient sediment routing, and reduced bank and channel stability from logging, road construction, and road use can combine to make streams wider and shallower, with fewer and shallower pools (Sullivan et al. 1987, Swanston 1991, Furniss 1991, Gregory et al. 1987, Hicks et al. 1991). Such streams are more susceptible to warming.

A number of studies have attempted to examine the cumulative effects of timber cutting at the watershed scale. A study on the Olympic Peninsula compared temperatures of 11 streams in unmanaged watersheds (less than 15% of mature forest in the watershed logged and no harvest within riparian areas) and 15 streams in managed watersheds (more than 15% of forest logged, or harvest within riparian areas) using continuous monitoring for one summer (Hatten and Conrad 1995). Water temperatures in the managed group were significantly warmer than in the unmanaged group. The difference was not explained statistically by elevation or the amount of shade in the monitored reach. The most important predictor of temperature was the proportion of the watershed in late seral stage forest, regardless of whether the basin was managed or unmanaged.

In three small watersheds in the western Cascades, Oregon, maximum stream temperatures increased 7° C and occurred earlier in the summer after clear cutting and burning in one basin and patch cutting and debris flows in another (Johnson and Jones 2000). Stream temperatures gradually returned to preharvest values over a 15-year period. ODEQ (1995) includes summaries of several studies concerning cumulative water temperature effects of logging, and effects of riparian and stream channel restoration on stream temperature recovery.

Adverse physiological and behavioral effects to Pacific salmon accrue not only from persistent high temperatures in summer, but from intermittent exposure to high temperatures, increased diurnal variation in water temperature, and altered cumulative exposure history of the organism (McCullough 1999). Adverse effects to salmonid fishes from warm water temperature can include: (1) increased adult mortality and reduced gamete survival during pre-spawn holding; (2) reduced growth of alevins or juveniles; (3) reduced competitive success relative to non-salmonids; (4) out-migration from unsuitable areas and truncation of spatial distribution; (5) increased disease virulence, and reduced disease resistance; (6) delay, prevention, or reversal of smoltification; and (7) potentially harmful interactions with other habitat stressors ((Zaugg et al. 1972; Adams et al. 1975; Zaugg and Wagner 1973; Zaugg 1981; Reeves et. al. 1987; Berman 1990; Marine 1992, 2004; ODEQ 1995; McCullough 1999; Dunham et al. 2001; Materna 2001; McCullough et al. 2001; Sauter et al. 2001. Poole et al. (2001) summarizes temperatures that would support various life stages of anadromous and resident salmonids, and discusses thermal dynamics in natural and altered watersheds.

Logging can have unexpected biological consequences related to temperature. In Carnation Creek, British Columbia, Canada, higher late winter and spring water temperatures following logging increased juvenile coho growth, leading to higher survival overwinter, but caused an earlier seaward migration of smolts, decreasing survival (Holtby 1998). Holtby concluded that increased temperatures: (1) can have quantifiable effects on salmonid populations, (2) these effects can influence more than one life stage simultaneously and in opposite directions, (3) the effects of perturbations at one life stage can persist throughout the remainder of the life cycle, and (4) for anadromous species, the effects of habitat perturbations during freshwater rearing can persist into the marine phase.

Compared to other riparian functions, the effects of altered microclimate following timber harvest on streams and fish are poorly understood. Since edge effects from clearcut harvest of Douglas-fir extended 30 to >240 m (98 to >787 feet) into the adjacent forest (Chen et al. 1995), clear cuts may affect adjacent riparian forests left as buffers for streams. Buffer strip width can affect air temperature and humidity in riparian areas (Ledwith 1996). Altered light regimes, humidity, wind, temperature, soil moisture and tree seed availability within buffer strips adjacent to harvested areas may foster a shift away from coniferous trees toward herbaceous or shrub vegetation that would not, over the long term, provide the volumes of wood needed to enhance fish habitat (Carlson et al. 1990, Hibbs and Giordano 1992). Shrubs may be less efficient at shading streams, (Carlson et al. 1990), possibly leading to higher stream temperatures.

Increases in sediment supply beyond the transport capability of the stream can cause stream channel instability, aggradation, widening, loss of pools, and a reduction in gravel quality (Sullivan et al. 1987, Swanston 1991). For salmon, these changes can mean reduced spawning success and smolt production when spawning areas are covered, eggs and fry are trapped or deprived of oxygen, food abundance or availability is reduced, and pools and interstitial spaces that provide cover to rearing juveniles are filled (Chapman and McLeod 1987, Bjornn and Reiser 1991, Hicks et al. 1991b).

4.1.2. Log Yarding and Site Preparation

Log yarding and subsequent site preparation activities (e.g. prescribed burning and scarification prior to planting) can increase soil exposure, runoff, and surface erosion (Chamberlin et al. 1991). The magnitude of effects depends on the type of equipment used; the location (e.g. proximity to stream channels), extent, and type of disturbance; slope; soil types; the time required for revegetation, and whether runoff can be concentrated by roads or other features. Murphy (1995) compared forest practice rules in California, Idaho, Oregon, Washington and Alaska and concluded that the buffers for small non-fish streams appeared to be "minimal or inadequate for sediment control."

4.1.3. Road construction

Road construction may degrade fish habitat no matter how well the roads are located, designed or maintained (Furniss et al. 1991). Construction of a road network can greatly accelerate erosion rates in a watershed (Haupt 1959, Swanson and Dyrness 1975, Swanston and Swanson 1976, Beschta 1978, Gardner 1979, Megahan 1987). Roads have been, and continue to be, a primary source of sediment delivered to streams in developed watersheds (Furniss et al. 1991, FEMAT 1993, Lee et al. 1997). Although erosion rates eventually decline after completion of road construction, unpaved road surfaces continually erode fine sediments, adding significant amounts of sediment to streams (Reid and Dunne 1984, Swanston 1991). The percentage of fine sediments in spawning gravels increased above natural levels when more than 2.5% of a basin area was covered by roads (Cederholm et al.1981, Cederholm and Reid 1987).

Road construction or improper maintenance on unstable slopes can greatly increase landslide rates relative to undisturbed forest (Swanson and Dryness 1975, Swanston and Swanson 1976, Furniss et al. 1991, McClelland et al. 1997, Robison et al. 1999), delivering large pulses of sediment to streams.

Road networks can intercept, divert, and concentrate surface and subsurface water flows, thereby increasing the watershed's drainage network, altering base and peak stream flows, and increasing landslide risk (Furniss et al. 1991, Montgomery et al. 1994, Wemple et al. 1996). Roads also can separate streams from their floodplains, interfering with groundwater flows into streams that can provide cold-water refugia (Coutant 1999, Poole and Berman 2001). Montgomery (1994) described simple procedures for determining required frequency of road drainage features (based on road drainage area and hill slope) needed to avoid concentration of runoff onto areas in a manner that could cause channel initiation and landslides. Roads and related ditch networks that discharge directly into streams provide a direct conduit for sediment (Fig. 2).

Figure 2. Clockwise from top left: Channel-like flow and sediment in road ditch, sediment discharge into riparian area (note culvert upper right of photo), and sediment plume in Panjab Creek. Vicinity of Meadow Timber Sale, Umatilla National Forest, 1993. Photos: Morris Owen, Washington Department of Wildlife.

Road type, density, location (including geological conditions, slope and proximity to streams), construction methods, drainage, surface type, overall condition, and usage all influence the effects of roads on salmonid habitat. This information is common to most watershed analyses and road system assessments.

Road density provides a useful index of road effects on salmonid habitats at larger scales (Lee et al. 1997). Another method that could be used to analyze potential effects of roads is provided in a conceptual model by Jones et al. (2000). They propose that the effects of roads on flood flows and debris flows are greatest downstream of individual stream crossings and areas of high densities of such crossings. They suggest road effects could be determined using (1) landscape stratification of stream susceptibility to floods and/or debris flows, and (2) densities of road-stream crossings, with an emphasis on mid-slope roads.

Improperly designed stream crossings can partially or completely block migration of adult or juvenile fish (Furniss et al. 1991). Migration barriers have significantly affected anadromous fish populations in the Pacific Northwest (Botkin et al. 1995, National Research Council 1996). For example, in the 532 fish presence surveys conducted in coastal Oregon basins during 1995, 15% (n = 79) of the confirmed upstream limits of fish use were due to human-created barriers. Road culverts made up the largest percentage (96%) of the barriers; the balance was various types of dams. An additional 3% of the surveys identified culverts that were impassable to anadromous fish but had upstream populations of resident trout (OCSRI 1997).

Alteration of stream channel geometry following culvert placement can cause upstream or downstream adjustments in stream channels that usually are detrimental to fish (Furniss et al. 1991). Road culverts and associated fills can also be a source of sedimentation, especially if culverts fail or become plugged with debris (Fig. 3) (Furniss et al.1991, Murphy 1995).


Figure 3. Culvert on Sheep Creek, Wallowa Whitman National Forest, that plugged with debris in June, 1993 and overtopped road (left), causing failure of road fill (right). Photos: Jeff Lockwood, NOAA Fisheries.

Roads built near watercourses can eliminate part of the riparian vegetation (Furniss et al. 1991), reducing LWM recruitment and shade. Roads and culverts can block downstream movement of LWM being carried in debris flows. Riparian roads constrain the natural migration of the stream channel where channel migration zones are present, and can sever streams from their floodplains.

4.1.4. Road Use and Maintenance

Besides increasing sediment yield, particularly when roads are wet (Reid and Dunne 1984), road use by logging trucks and equipment increases the risk of fuel and chemical spills. Effects of road use depend on road type, location, drainage, surface, condition, season and intensity of use, and the type and condition of stream crossings. Road reconstruction and maintenance prior to use for timber hauling can reduce sediment input to streams.

4.1.5. Forest Chemicals

Chemicals used in forest management activities include herbicides, insecticides, fertilizers, dust abatement sprays, and fire retardants. They can enter streams directly or be carried by runoff water. All of these chemicals can affect salmonids through their direct toxicity or by altering primary and secondary production and influencing the amount and type of food available (Norris et al. 1991, Spence et al. 1996). Risks associated with these compounds depend on the form (including inert ingredients, carrier agents, and surfactants) of the chemicals, application method and rate, whether buffers are maintained, soil type, weather conditions during and after application, and persistence of the chemicals in the environment.

When chemicals are transported near or across streams, a chemical-spill hazard exists (Furniss et al. 1991). NOAA Fisheries commonly has not included forest chemicals in agreements for non-Federal forest lands (e.g., habitat conservation plans), although it is developing experience with certain chemicals (particularly herbicides) through ESA section 7 consultations.

4.1.6. Hydrological Effects

Hydrological responses to clearcut logging are highly complex, and are affected by myriad factors including vegetation conditions elsewhere in the watershed; precipitation form, timing and amount; soil types, elevation, and aspect of harvest units; and the type and extent of other disturbances (such as roads and landings) associated with the timber sale. Nevertheless, the preponderance of information indicates that in created forest openings, the combination of more precipitation reaching the ground, rain-on-snow events, and less evapotranspiration of water by trees can combine to significantly increase soil moisture and water yield from cut areas compared to uncut areas (Chamberlin et al. 1991, Hicks et al. 1991b).

Greater water inputs from logged areas into streams can increase the volume of peak flows and alter the timing of peak flows (Satterlund and Adams 1992, Jones and Grant 1996). These hydrological changes can increase bed scour and accelerate bank erosion, which in turn can: (1) increase stream sediment load and lower habitat diversity (Chamberlin et al. 1991), (2) displace juvenile salmonids (Cederholm and Reid 1987), and (3) disturb or destroy redds (USDA 1982, Bjornn and Reiser 1991, Rhodes et al. 1994). Increased surface and subsurface water flows following logging may result in accelerated erosion in swales and headward cutting of ephemeral stream channels into swales over a period of several years. This process has been demonstrated in unstable Idaho batholithic soils (Megahan 1987) and in volcanic soils in the White Mountains of Arizona (Heede 1991).

Reiter and Beschta (1995) summarized studies of timber harvest effects on peak flows that were done in nine rain-dominated coastal streams in Oregon (four streams), British Columbia, Canada (four streams), and California (one stream). Eight of these streams showed an increase in peak flows following harvesting and only one showed a decrease. Changes in peak flows did not occur in the two largest watersheds. A regression analysis of twelve previously published Pacific Coast studies by Stednick (1996) suggest a harvest of at least 25% of a watershed is needed to measurably increase annual water yield (although none of the studies examined areas where less than 25% of the watershed had been cut).

In small (1 km^2) basins in the western Cascades Range of Oregon, Jones and Grant (1996) found that "complete clear-cutting without roads produced significant increases in fall events, which are mostly small, and winter events, which range from small to large, but not for large events as a group." In small basins with both roads and 31% patch clearcuts, all sizes of peak discharges increased, with especially prolonged responses in winter storms. Jones and Grant (1996) also found increases in peak flow in large (60 to 600 km^2) basins that were detectable with only a 5% or greater difference between basins in cumulative area cut.

Thomas and Megahan (1998) and Beschta et al. (2000) re-analyzed the data presented in Jones and Grant (1996) and found more conclusive results for peak flow changes in small watersheds than in large watersheds. Thomas and Megahan (1998) concluded that peak flow increases resulting from clearcuts and clearcuts with roads were not detectable for flows with greater than 2-year return intervals (i.e. effects were detectable only for small storms). Beschta et al. (2000) found larger percentage increases for 1-year recurrence flows than for 5-year recurrence flows in the small basins. Relatively frequent flows (occurring every 1 to 5 years) can be the most be important for sediment transport and channel formation in many regions (Ziemer and Lisle 1998), although in mountain streams large infrequent flows may be more important than in lowland streams (Beschta et al. 2000). The inability to detect changes in peak flows after logging in some situations may be due to high variance in the data rather than absence of an effect (Rice et al. in press).

Hydrological responses to upland forest clearing often are most pronounced at elevations and locations where rain-on-snow events are common (Christner and Harr 1982, Harr 1986). In many watersheds, peak flows appear to rise in a curvilinear fashion with increased timber harvest (Grant 1987), rather than failing to change until after a threshold of forest clearing has been reached. However, related effects (such as sediment mobilization and channel modification) may not be evident until a peak flow threshold has been reached (Grant 1987).

The timing of peak runoff also can be altered by logging. Snow may melt earlier in cut areas than in adjacent forested areas, particularly if the logged area is not shaded by adjacent trees or hills. Summer stream flows may increase temporarily after logging (Hicks et al. 1991a, b), improving summer rearing habitat, but may then decline for extended periods (Hicks et al. 1991a), reducing habitat quality. To some extent, the timing of peak runoff can be controlled by designing the size, shape and orientation of cut areas (Chamberlin et al. 1991, Satterlund and Adams 1992). The issues of hydrological alterations from upland logging and possible effects on salmonid habitats are unsettled scientifically and somewhat contentious as policy matters.

Localized hydrological effects do not necessarily equate to detrimental biological effects on fish. Ideally, the identification potential adverse effects by using thresholds of concern such as are given in NOAA Fisheries (1996) would lead to watershed-specific analysis to determine: (1) the limits of fish distribution in relation to the area of likely hydrological changes; (2) whether the predicted hydrological changes would be likely to affect fish habitat locally (e.g. by reducing streambank stability or scouring redds) or to cause cumulative watershed effects (i.e. effects that can be transmitted downstream, such as mobilization of bedload sediment); and (3) how any local or cumulative effects on physical habitat are likely to affect the survival, growth, reproduction and behavior of listed fish.

4.2. Effects on Upland Forest Functions

4.2.1. Mass Wasting

Recently-logged areas often experience an increased rate of mass wasting in the form of shallow, rapid landslides and debris flows (Swanston and Swanson 1976, Sidle et al. 1985, Swanston 1991, Robison et al. 1999, Montgomery et al. 2000). Likely reasons for this increase include reduced soil shear strength, and increased soil moisture due to reduced canopy interception of precipitation and reduced evapotranspiration following harvesting. Soil shear strength decreases as tree roots gradually decay over a period of 2-10 years (Ziemer 1981a, 1981b; Sidle et al. 1985). Steep, convergent land forms, which constitute a relatively small percentage of forest lands, are most susceptible to landslides (Benda and Cundy 1990, Montgomery et al. 2000). Landslides originating from harvested hillslopes, and that travel along harvested stream channels, will deliver primarily sediment rather than LWM to streams (Hicks et al. 1991a, Reeves et al. 1995; see also discussion in Section 3.2. above). Forestry activities are not as likely to affect deep-seated landslides, although road or other excavations at the toe of such features may affect their stability.

4.3.2. Buffer Zone Edge Effects

The typical sharp demarcation between the edge of riparian buffers and upland clearcut harvests is not analogous to natural forest patterns (IMST 1999) and may increase blow-down of trees in the buffer. Geographically patchy but substantial mortality of trees by blowdown over periods of 1 to 15 years was found in stream buffer strips surveyed in the Cascade Mountains of western Oregon (Steinblums et al. 1984) and in the Oregon Coast Range (Andrus and Froehlich 1992). In both studies, persistence of trees over time did not appear to be affected by buffer width. However, neither study examined whether blowdown up to the stream edge was more likely with narrow buffers. Blowdown in wider buffers might be concentrated on the exposed perimeter, rather than in the more protected interior along the stream, thereby retaining shading, sediment filtering, and large wood recruitment functions over time. The studies described above demonstrated that exposure to damaging winds, local topography, soil conditions, and tree species all affect tree blowdown, and should be considered when planning the layout of stream buffer strips.

Partial blowdown of trees within buffer strips can benefit salmonid fishes in the long term by increasing large fallen wood in the stream channel (Bisson et al. 1987, Murphy 1995). However, windthrown trees may represent short-term sources of sediment (Steinblums et al. 1984). Also, complete blowdown of trees to the stream edge would reduce stream shading and the sediment filtering capacity of the buffer strip, and would delay future recruitment of LWM.

4.3. Biological Functions

Beaver often are removed on managed forest lands to protect culverts from being plugged and to protect roads from flooding. Beaver dams may be removed to reduce the risk of dam break floods. Beavers may also be displaced by removal of riparian vegetation, particularly alders, is removed. Removal or displacement of beaver eliminates the beneficial effects of beaver activity on salmonid habitat that are described in Section I. C. above.

4.4. Cumulative Watershed Effects

A watershed is a logical unit for analysis of potential effects of land management (particularly for actions that are large in scope or scale). Healthy salmonid populations use habitats throughout watersheds (Naiman et al. 1992), and riverine conditions reflect biological, geological and hydrological processes operating at the watershed level (Nehlsen et al. 1997, Bisson et al. 1997, NOAA Fisheries 1999). Most land management effects on streams and rivers are carried downstream readily, and some can travel upstream as well (*e.g.*, channel head cutting). Also, watershed divides provide clear boundaries for analyzing the combined effects of multiple activities (National Research Council 1996). A watershed perspective is needed to identify and assess refugia or highly productive habitat patches, and to assess connectivity between these areas and between fish population segments (Sedell et al. 1990, Naiman et al. 1992, Li et al. 1995, Bisson et al. 1997). For these reasons, habitat conservation and restoration strategies are most likely to be effective if carried out at the scale of the watershed (or composites of multiple watersheds in a species' range; Reeves et al. 1995, Frissell and Bayles 1996), not the stream reach (Reeves and Sedell 1992, Botkin et al. 1995, National Research Council 1996, Nehlsen et al. 1997).

Although NOAA Fisheries prefers watershed-scale conservation planning and analysis due to greater efficiency in reviewing multiple actions, increased analytic ability, and the potential for more flexibility in management practices, often it must analyze effects at geographic areas smaller than a watershed or basin due to a proposed action's scope or geographic scale. Analyses that are focused at the scale of the site or stream reach may not be able to discern whether the effects of the proposed action will contribute to or be compounded by cumulative watershed impacts[5] (particularly where a watershed analysis is not available). This loss of analytic ability typically should be offset by more conservative land management and analysis in order to achieve parity of risk with the watershed approach (NOAA Fisheries 1999).

Although individual land management activities by themselves may not significantly harm salmonid habitats, collectively they may degrade habitat and cause long-term declines in fish abundance (Bisson et

[5]Reid (1998) defined cumulative impacts as impacts that are influenced by multiple activities or causes, and defined cumulative watershed impacts as cumulative impacts that influence or are influenced by the flow of water through a watershed. Reid (1998) also noted that most impacts that occur away from the site of the triggering land-use activity are cumulative watershed impacts. The term "cumulative effects" also has been used to describe additive or synergistic effects of management practices on ecosystems (Spence et al. 1996).

al. 1992). Changes in sediment dynamics, streamflow, and water temperature are not just local problems restricted to a particular stream reach, but problems that can adversely affect the entire downstream basin (Grant 1988, Reid 1998). For example, increased erosion in headwaters, combined with reduced sediment storage capacity in small streams due to the loss of instream LWM, can overwhelm larger streams with sediment (Bisson et al. 1992, Reid 1998). Likewise, increased water temperature in headwater streams may not harm salmonids there but can contribute to downstream warming (Bisson et al. 1987, Bjornn and Reiser 1991).

5.0 Considerations for Developing Conservation Measures

This section includes a list of potential, general considerations for the development or negotiation of conservation measures for non-Federal forest management agreements. The measures in the list were adapted from previous agreements (particularly the Forests and Fish Report in Washington state), habitat conservation plans, and other sources. In some cases, existing rules or agreements may be such that only a subset of the considerations would need to be included.

5.1. Accurate classification of water bodies as to their ability to support fish, and flow characteristics.

Effective conservation of fish habitats and populations requires specific geographic knowledge of existing and potential fish habitats as well as the higher elevation, non-fish bearing stream systems that create and influence them by contributing nutrients, water, gravel and LWM beneficial to the downstream aquatic ecosystem. The following measures pertain to classification of water bodies:

5.1.1. Forest practices should be tailored to protect and reinforce the functions and roles of at least three different stream classes in the continuum of the aquatic ecosystem: fish-bearing streams that are currently or potentially capable of supporting fish of any species, perennially or seasonally; perennial, non-fish bearing streams, which include spatially intermittent streams, and seeps and springs connected to them; and seasonal, non-fish bearing streams (intermittent or non-perennial), that flow water, of any flow volume, some time during the water year, and seeps and springs connected to them.

5.1.2. With respect to fish-bearing streams, classification can be based on either fish surveys or modeling based on habitat suitability. Some states and landowners require or perform fish surveys only when activities are proposed in an area. This can be a problem due to seasonal changes in fish distribution. Others have or are collecting fish distribution data over time for a more comprehensive database. Either forestry or fisheries agencies, or both, may maintain fish distribution information that can be used to develop or confirm proper stream classification.

5.1.3. Models also may be used to describe likely fish distribution. These models may be simple (e.g. based on drainage area) or based on multiple variables (e.g. drainage area, slope, channel confinement). Use of models allows patterns to be more rapidly described at larger scales than fish surveys, avoids errors based on sampling problems (e.g. inadequate gear or sampling effort), and avoids potential harm or harassment of ESA-listed fish during sampling. Models also foster management based on potential distribution of fish, rather than current distribution that may be truncated due to variation in fish abundance, variation in stream flow, or impassable road culverts.

5.1.4. Landowners, regulatory agencies, and the public should have reasonable access to fish distribution and stream classification information, preferably through a geographic information system, or some other accessible repository

5.2. Provisions requiring proper design, maintenance, and upgrading existing and new forest roads.

In order to minimize the effects of roads on fish habitat, forest practices need to address road density, location, design, construction impacts, riparian impacts, surfacing, drainage (including the ability to pass storm flows and large wood through culverts), control of use when roads are wet, closure and/or decommissioning of roads in sensitive areas (e.g. riparian areas and low to mid-slope elevations on potentially unstable terrain), and long-term maintenance.

NOAA Fisheries encourages inclusion of a requirement for the development and implementation of a road management plan by each land owner that would require: (1) an inventory of the condition of all roads within that management ownership, and (2) a plan for repair, reconstruction, maintenance, access control, and where needed, abandonment and/or obliteration of all existing and legacy roads within a land ownership. Road maintenance plans for all new or reconstructed roads should address routine operations (grading, ditch cleaning, etc.), placement of spoil or graded sediments, retention of LWM at stream crossings, placement of LWM recruited in proximity to riparian roads, and emergency repairs.

Also needed are measures that would:

5.2.1 Require avoidance of road construction or reconstruction in riparian areas unless alternative options for road construction would likely cause greater damage to aquatic habitats or riparian functions. Avoid duplicative roads and stream crossings. Consider temporary roads and stream crossings where practicable. Consider including measures requiring mitigation for riparian functions altered by the road, such as replacement of trees or basal area removed for the road prism (as is required in Washington state), placement of trees that have been removed for construction of the road into the stream channel, and placement of trees that have fallen across or onto the fill or cut slopes of riparian roads to the streamward side of the road as part of routine or emergency road maintenance.

5.2.2. Prohibit road construction or reconstruction on potentially unstable slopes unless an analysis involving qualified geotechnical personnel demonstrates that road construction can proceed without increasing the risk of management-related landslides, sediment delivery, or other impacts to stream channels or water bodies. The public should have an opportunity to review and comment on such analyses. See Section 5.4 below for information concerning identification of potentially unstable slopes.

5.2.3 Ensure that new and reconstructed roads will not impair hydrological connections between stream channels, ground water, and wetlands; will not increase sedimentation to aquatic systems; will use only clean fill materials; will have adequate drainage and surfacing; and will not discharge drainage water directly into streams or onto potentially unstable land forms (e.g. concave hollows or headwalls on steep hills). Montgomery (1994) describes simple procedures for determining required frequency of road drainage features (based on road drainage area and hill slope) needed to avoid concentration of runoff onto areas in a manner that could cause channel initiation and landslides

5.2.4. Require stream crossings to provide adequate fish passage for both adults and juveniles, accommodate a 100-year flood without over-topping the road, and pass adequate LWM. Refer to NOAA Fisheries' Anadromous Salmonid Passage Facility Guidelines and Criteria (currently draft), Section 9: Fish Passage Criteria and Guidelines for Culverts and other Road Crossings. Existing state regulations and guidance may be adequate if they ensure fish passage as well as NOAA Fisheries' guidance.

5 2.5. Require best management practices (BMPs) in all other aspects of forest road operations, including use for log hauling, recreational use, and seasonal closure as needed to maintain and improve water quality and stream habitats and to meet seasonal life history requirements for fishes.

Additional information about planning, designing, constructing, reconstructing, maintaining and closing forest roads is detailed in Weaver and Hagans (1994). The comprehensive road maintenance practices in the Transportation Maintenance Management System Water Quality and Habitat Guide (Oregon Department of Transportation 1999) have been endorsed by NOAA Fisheries in Limit 10 of its June, 2000 ESA section 4(d) rule, and may be instructive for those reviewing road maintenance measures.

5.3. Achievement and maintenance of the riparian, floodplain and groundwater functions in areas of watersheds that affect conditions and processes in fish-bearing streams. The functions include litterfall and large wood recruitment; stream bank stability; sediment filtration; stream shading; connectivity of riparian areas, floodplains and groundwater sources; and microclimate factors such as air and soil temperature, wind speed, and relative humidity.

Functions of riparian forests can be achieved and maintained using either a natural or active strategy for succession and growth. A natural strategy would establish riparian management zones (RMZs) within which no silvicultural treatments occurs. This strategy is appropriate when all available trees in the RMZ need to be retained and allowed to grow and succeed to achieve a desired future condition (DFC) of a mature riparian forest, or where a landowner does not choose to manage the RMZ. NOAA Fisheries has approved of strategies in which fish-bearing streams have RMZs widths equal to at least 2/3 to 3/4 of the height of a site-potential tree height for typical dominant conifers. Disturbance from activities such as road crossings and cable yarding corridors usually would be avoided. Where ground and vegetation disturbance is unavoidable, it would be limited to a small percentage of the riparian area. Riparian stand development would be allowed to proceed under natural rates of growth and succession to mature conditions, undisturbed by future harvest or silvicultural activities.

A managed succession and growth strategy can include variable width RMZs within which silvicultural treatments are allowed. These treatments would be prescribed through silvicultural guidelines that ensure that the riparian forest stand is on a growth and succession pathway toward a desired future condition (DFC) of a mature riparian forest. Once the trajectory of growth toward the DFC was achieved, the riparian forest would remain on that trajectory without further harvest or silvicultural treatment.

Measures for both the natural succession and managed growth strategies should include:

5.3.1. Continuous RMZs along all fish-bearing streams. Widths of the RMZs could vary depending on site productivity, silvicultural options for achieving DFC, or other factors, but commonly have been at least 80 ft or greater in width for the poorest productivity class. As site productivity increases so would the RMZ widths.

5.3.2. A core zone, commonly 30-50 ft in width, within which no harvest or salvage would occur to protect streambank stability and litterfall and to ensure a high level of other riparian functions immediately adjacent to streams, and where equipment use would be restricted to minimize soil compaction, sediment generation, damage to residual vegetation, etc. This width would be measured horizontally from the edge of the bankfull stream channel or, where a channel migration zone is available, from the edge of the channel migration zone.

5.3.2. A second zone, commonly extending out to a distance equal to 2/3 to 3/4 of a site potential tree height for fish-bearing streams (or sometimes for a lesser distance for non-fish bearing streams), that provides a high level of other riparian functions (large wood recruitment, stream shading, riparian-floodplain-groundwater connectivity, sediment filtration, and microclimate factors).

5.3.3. In some cases, for fish-bearing streams, an outer zone extending from the outer edge of the second zone out to a distance from the stream or channel migration zone equal to the height of a site potential tree height. This zone provides a partial buffer to windthrow of the other zones, and contributes to meeting other riparian functions.

5.3.4. Disturbance limits (e.g. 20-percent of the overstory canopy along the stream length for yarding corridors, and 10-percent ground disturbance). Ground disturbance includes, but is not limited to, yarding corridors, soil compaction and exposure, stream crossings and other effects that are a product of log yarding and equipment use. Tree retention to attain DFC over time would need to be achieved regardless of the area modified for yarding corridors.

5.3.5. Shade retention along fish-bearing streams, sensitive sites such as seeps and springs, and other groundwater source areas must be 100 percent of the available shade, unless shade levels incorporated in state or regional water temperature models or standards can be shown to meet fish life history requirements.

5.3.6. For non-fish-bearing streams, sufficient shade should be maintained to prevent temperature increases or other alterations of natural thermal regimes in fish-bearing waters, and should include protection of sensitive sites as described above. RMZ characteristics needed to attain this level of shade vary depending on riparian stand characteristics, stream size, availability of topographic shading, extent of groundwater interaction, etc. Results of modeling exercises completed for total maximum daily loads prepared under the Clean Water Act often provide information about riparian vegetation characteristics needed to meet water quality standards and should be used where available.

5.3.7. For the managed succession and growth strategy, treatment guidelines by tree species and region that address stand composition, stocking levels, tree selection, spacing, and other common forest metrics for a given stand age and condition necessary to achieve DFC; require protection and release of residual or understory tree species that would form a desirable component of a future mature riparian forest; requires retention of structural diversity in the stand, including openings (spatial diversity), species diversity, and emphasis on tree retention on topographic features that increase the probability of tree fall toward stream channels; and guidelines for maintaining shade necessary to meet fish life history requirements.

5.3.8. Guidelines for conversion of hardwood-dominated riparian areas that cannot achieve the DFC, to include a core zone (commonly 50-ft wide) that would not be managed and would be disturbed only for road crossings and yarding corridors; retention of all overstory conifers; and a minimum tree retention standard for the outer zone(s). Hardwood conversion generally should be limited to sites where there is clear evidence that the riparian area was previously conifer-dominated.

5.3.9. Guidelines for salvage of dead or downed timber in the RMZs (outside of the core zone) that require retention of coarse woody debris on the riparian forest floor at levels seen in mature forests; retention of live or standing dead trees in the inner zone that may fall into the stream and that can add structural and species diversity to the future riparian forest, retention of all dead or downed timber within stream channels, channel migration zones, and core zones; and minimization of disturbance from site preparation necessary for replanting.

5.3.10. Guidelines for active restoration. To be effective, active restoration should include both the removal of high-impact, human-caused disturbances in salmonid habitats, and the manipulation of key in-stream, riparian vegetation, and floodplain features to accelerate the development of desired ecological conditions (National Research Council 1996). Well-intentioned restoration that occurs without removing adverse impacts can provide only transient benefits without achieving long-term improvements (Beschta et al. 1994). Furthermore, restoration that ignores the dynamic nature of fish populations and habitat conditions will likely be ineffective (Bisson et al. 1997).

5.4. Identification of unstable slopes and debris flow paths at both planning and project-specific levels, and protection from activities that alter landslide rates and composition in areas that can affect fish habitat.

Management of hazards from mass slope failures requires consideration of at least two factors: the likelihood of mass failure, and the likelihood of delivery to streams. There are a number of computer models that predict stability based on slope, topography, rainfall, and other variables, including but not limited to SHALSTAB. Papers developing the SHALSTAB model and showing its application include: Dietrich et al. 1992, 1993, 1995; Montgomery and Dietrich 1994; and Montgomery et al. 2000. This model works various topographic data sources such as digitized 7.5 minute USGS quadrangle maps with enhanced topographical contours at 10-m intervals.

The model assigns to each 10-m topographic cell a relative hazard rating (low, medium, or high). These relative hazard ratings can be used in planning the layout of timber harvest units. Some inner gorges (See Kelsey 1988 for a definition) may not be included in the model results and would need to located by field surveys, since these features do not typically show up on topographic maps.

The Oregon Department of Geology and Mineral Industries is working with Oregon Department of Forestry (ODF) to map debris flow hazard areas in the Oregon Coast region to meet the requirements of Oregon Senate Bill 12, which is designed to protect human life and property, but does *not* address concerns related to water quality or fisheries. Information about the Oregon mapping is available at http://www.lcd.state.or.us/landslides/maptech.html. Also, the Oregon State Habitat Office has worked with the Northwest Region's geographic information systems (GIS) coordinator to map landslide hazards in the range of Oregon Coast coho using SHALSTAB and 10-m topographical countours. Data for these maps resides with the GIS coordinator, now located in the Protected Resources Division of NOAA Fisheries. The Coastal Landscape and Analysis Modeling Study has completed another version of landslide and debris flow mapping for the Oregon Coast Range.

Figure 1. Example of output from SHALSTAB shallow landslide model using 10 m USGS topographic data (left) and 2-m intervals generated by laser altimetry (right). Higher values of log q/T represent areas where less rainfall is needed to generate slope failure. Purple represents chronically unstable slopes and red represents the highest risk of failure. Figure: Dr. William Dietrich, University of California, Berkeley.

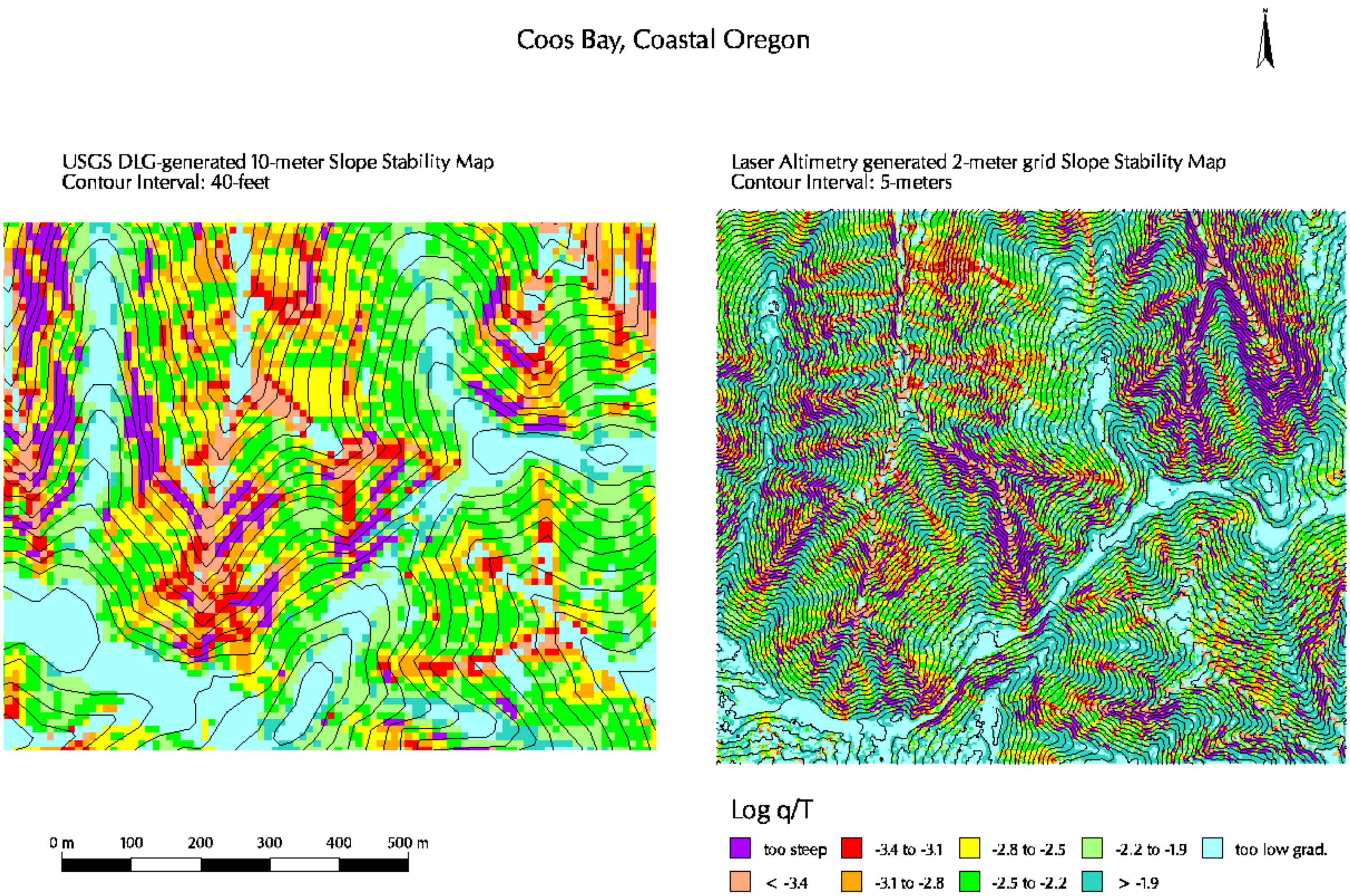

Figure 16.

In Washington state, the Cooperative Monitoring, Evaluation and Research Committee is carrying out two projects to improve detection of unstable slopes on forest lands. The Regional Landform Identification Project will identify region-specific high-hazard landforms not identified by the definitions in the forest practices rule. The Landslide Hazard Zonation Project will identify and map unstable slopes statewide using methods similar to those in the mass wasting module of the state's watershed analysis procedures. The results of these projects are intended for use by regulatory staff of the Department of Natural Resources, landowners, and staff from cooperating organizations to aid in the identification of unstable slopes during review of forest practices applications.

5.4.2. Management of unstable slopes and debris flow paths – areas where NOAA Fisheries has *not* approved or endorsed forest practices: Once a suitable map of landslide hazards has been developed or obtained for an area, a landowner would have several options for how to proceed. If substantial parts of an ownership fall in the high hazard category, NOAA Fisheries would encourage a landowner to arrange a ground-based, site-specific analysis by a professional geologist or geotechnician in order to identify the specific areas of the unit posing a high risk from timber harvest (e.g., bedrock hollows, steep inner gorges, steep planar slopes), while making timber outside of the high hazard areas available for harvest. Without investing in a more intensive on-site inspection, the landowner could avoid timber harvest on mapped high hazard areas and thereby also minimize the likelihood of unauthorized *take* of ESA-listed Pacific salmon (e.g., obliteration of redds, destruction of habitat) that could occur if subsequent mass failures related to timber harvest deliver sediment to fish habitat.

Once potential failure sites are categorized based on a computer model or site-specific geotechnical investigation, models (e.g., Benda and Cundy 1990) would be used to predict whether debris flows (downslope or downstream propagation of slope failures that tend to increase in volume and effects they move downstream; Swanston 1991) will reach particular streams based on stream gradient, tributary junction angle, and other factors. This would allow one to determine which potential landslide initiation sites pose the highest risk of delivery of sediment to streams that are important to ESA-listed Pacific salmon. The highest risk of harm to ESA-listed species from timber harvest would be on sites with both high potential for failure and high potential for delivery of sediment to streams used by ESA-listed species, followed by those sites that may deliver to perennial streams uninhabited by ESA-listed species; timber harvest on such sites generally would not be consistent with the conservation of ESA-listed Pacific salmon.

5.4.3. Management of unstable slopes and debris flow paths – Washington state. NOAA Fisheries has endorsed the unstable slopes recommendations in the Forests and Fish Report as stated in Limit 13 of its ESA section 4(d) rule. NOAA Fisheries assisted in developing the Washington state rules and procedures that are summarized below, but the rules and procedures still are under review by NOAA Fisheries for possible approval under Limit 13 of the ESA section 4(d) rule or in an incidental take permit for a habitat conservation plan.

In Washington state, decisions about forest management on unstable slopes and landforms (hereafter referred to as unstable slopes) are determined through an outcome-based decision-making process conducted in accordance with the Washington forest practice rules and the State Environmental Policy Act (SEPA). Under the process, the Department of Natural Resources evaluates proposed timber harvest and construction activities on unstable slopes to determine if they will have a probable significant adverse impact. The determination is based on the agency's evaluation of the proposal, conducted in consultation with other affected agencies and Indian tribes, as well as comments received from interested parties through the SEPA review process.

Under the Washington process, in areas where watershed analysis has been conducted and approved, management prescriptions are in place to address unstable slopes, and there is no additional analysis. If proposals deviate from the approved prescriptions, the forest practices application is considered an "alternate plan", is classified as a IV-Special application, and is subject to review under SEPA. The rules require that applicants complete an environmental checklist for Class IV-Special forest practices applications. Applicants must conduct and submit a geotechnical assessment of proposed forest practice(s) by a qualified expert. The assessment must evaluate: 1) the likelihood that the proposal will cause movement on the potentially unstable slopes or contribute to further movement, and 2) the likelihood of sediment or debris delivery to any public resource or in a manner that would threaten public safety [WAC 222-10-030(1)]. The assessment must also identify any measures that would mitigate the identified hazards and risks.

5.5. Measures that limit soil disturbance and sediment generation.

Riparian disturbance is discussed under number 3 above, and sediment concerns for roads are discussed under number 2 above. Other relevant measures could include restricting ground-based yarding based on slope (commonly prohibited on slopes over 30-35%), and slash treatment criteria.

5.6 Measures that address risks to water quality from toxic materials.

5.6.1. Work with the landowner to develop a fuel transport, storage and spill contingency plan.

5.6.2. To reduce the staging area and potential for contamination, ensure that only enough supplies and equipment to complete a specific job will be stored on-site.

5.6.3. Complete vehicle staging, cleaning, maintenance, refueling, and fuel storage in a staging area placed 150 feet or more from any stream, water body or wetland.

5.6.4. Inspect all vehicles operated within 150 feet of any stream, water body or wetland daily for fluid leaks before leaving the vehicle staging area. Repair any leaks detected in the vehicle staging area before the vehicle resumes operation. Document inspections in a record that is available for review.

NOAA Fisheries commonly has not covered the use of forest chemicals (e.g., insecticides, herbicides) in ESA agreements for non-Federal lands. More information on herbicides is available in the online guidance for this subject.

5.7 Measures to conserve beaver populations.

5.7.1. Work with state and Federal (i.e., Animal and Plant Health Inspection Service) wildlife agencies to minimize removal of beaver (both commercial and recreational) in areas important to fish.

5.7.2 Avoid silvicultural activities (e.g. alder conversion) harmful to beaver where it would conflict with beneficial beaver activity.

5.7.3 Replace culverts with bridges where there are chronic culvert plugging problems that induce beaver removal, or install culvert protective devices that do not impede fish passage for either adult or juvenile passage.

5.7.4 Avoid the siting of new structures in flood plains and low-elevation areas where beaver ponds are likely to cause flooding.

5.7.5 Undertake only partial removal of beaver dams using mechanical means, under the guidance of a fishery biologist, where action is necessary due to severe flooding hazards.

5.8. A process for evaluating and minimizing the cumulative effects of multiple forest practices for all ownerships and activities within a watershed.

Consideration of landscape-scale conservation needs for Pacific salmon populations (e.g. refugia habitats and habitat connectivity) may be possible with single owners of large tracts but difficult where there are multiple landowners in a basin. However, such an approach greatly increases the likelihood that forest practices can be managed in a way that promotes the protection and restoration of Pacific salmon (IMST 1999). Possible approaches for analysis and management of cumulative include the following:

5.8.1. Reid (1993, table 5) lists eight procedures for predicting cumulative watershed effects.

5.8.2. The University of California Committee on Cumulative Watershed Effects (Dunne et al. 2001) recommended the use of spatially explicit mathematical modeling of watershed processes to estimate how different land use scenarios alter the risk of damage to ecosystem values.

5.8.3. The Caspar Creek Experimental Watershed Study is a cooperative venture of the U.S. Forest Service's Redwood Sciences Laboratory and the California Department of Forestry and Fire Protection that has been studying the nature of hydrologic, erosion, and sedimentation impacts of logging operations on northern California watersheds since 1962. A wealth of or information on cumulative effects of forest management developed by this project is available online at http://www.fs.fed.us/psw/topics/water/caspar/

5.8.4. The Coastal Landscape Analysis and Modeling Study (CLAMS) is a multi-disciplinary research effort that seeks to analyze the aggregate ecological, economic, and social consequences of forest policies of different land owners in the Oregon Coast Range. Analysis of timber harvest trends on private lands in western Oregon indicates disturbance of a greater proportion of forest lands over time in order to remove about the same volume of timber, as increasingly younger stands with lower average volumes per area are harvested (Alig et al. 2000). The CLAMS project also has projected increasing fragmentation of forests into distinct age classes in the forests of western Oregon.

Based on the involvement of one of the participants in this project (Lockwood) in the development of procedures for describing the status of environmental baseline and determining effects of proposed land management actions in montane forest lands ("matrix" paper, NOAA Fisheries 1996), NOAA Fisheries likely incorrectly referred exclusively to ECA as a measurement of watershed disturbance history, relying in part on studies summarized in Satterlund and Adams (1992) from both snow-dominated watersheds (Table 11.1, p. 242-243) and rain-dominated watersheds (Table 11.2, p. 254-256) for which a variety of methods likely were used. These studies, all of which were characterized by Satterlund and Adams (1992) in terms of percentage decrease in forest cover due to logging or other factors, demonstrated increased water yields following as little as a 16% reduction in forest cover (Table 1, road and patch cut treatment, conifer forest, Idaho, p. 243). Based on these results, other literature examined, and discussions with an expert panel concerning logging effects in the Snake River basin, NOAA Fisheries settled on 15% ECA as a regional indicator of risk from reductions in forest cover. NOAA Fisheries likely did not intend to establish ECA as a mandatory means for assessing cumulative watershed effects, or to establish a 15% ECA management threshold for forest lands.

5.9. Enforcement provisions to ensure compliance with rules.

Details to be added in later versions.

5.10. If provisions for issuance of variances from standard practices are included, they should require equivalent protection of ecological functions.

Details to be added in later versions.

5.11. Monitoring requirements that managers can use to determine how well forest practices are being implemented, how well they comply with rules, and how effectively the regulations are protecting fish habitat and watersheds.

Details to be added in later versions.

5.12. Adaptive management provisions to allow the rules to be updated as new scientific information and monitoring results become available.

Details to be added in later versions.

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Appendix A
Summary of State Regulation of Non-federal Forest Lands in Washington, Idaho, and Oregon
Rick Edwards, Steve Keller, and Jeff Lockwood

This is a summary of state forest practice rules that does not include all of the details needed to evaluate the rules. For details please consult the complete rules (links are in column titles) and any relevant guidance issued by the state. There are several important topics not covered by this table including riparian forest objectives and metrics, yarding, site preparation, reforestation, variances, and enforcement. Sources of information include state-published forest practice regulations, reports, and legislation known to the document's authors. The intent of this comparison is to compare and contrast the variety of approaches to forest land management in the region and not to address the adequacy of any prescription under the ESA.

Prescription, function, or process	**Washington**	**Idaho**	**Oregon**
Water Body Classification	3-tiers: S (shorelines of the state– all streams >20 cfs mean annual flow, all lakes and ponds >20 acres, all marine waters of the state, & all associated wetlands); F (fish-bearing streams, **domestic/hatchery diversions, w/in campgrounds, ponds, impoundments and off-channel habitat**; N (non-fish bearing streams). GIS-based predictive fish habitat model for mapping water types (under development)	2-tiers: I (domestic water supply or important for spawning, rearing, migration of fish), and II (few, if any, fish for spawning and rearing, or, if unknown, <240 acres watershed upstream in north forest region, or <460 acre watershed upstream in south forest region). Known fish-bearing streams identified by IDFG bios, unknown based upon watershed acreage	9-tiers: small, medium and large for fish, non-fish (type N), and domestic water use only (type D) streams Classification by current game fish use based on fish surveys

Roads Assessment and Planning	Unstable slope screening, limitations on riparian-adjacent roads, reduced road density	Avoid road construction within SPZs except at approaches to stream crossings; roads to drain naturally by outsloping or insloping with cross-drainage and grade changes; drainage structures will minimize direct discharge of sediment into streams.	Avoid and minimize risks to channels, floodplains; avoid unstable slopes, riparian areas, channels, floodplains where viable alternatives exist. Use existing roads where practicable.
Construction	Full bench on slopes >60%, drainage systems to pass 100 yr flood, avoid intra-basin transfers, closer culvert spacing to disperse sediment to forest floor	End-haul excess material from steep slopes or high risk sites; full bench on slopes >60%; drainage systems to pass 50 yr flood; earthwork postponed during wet periods.	End-haul excess material from steep slopes or high risk sites; avoid and minimize landslide risk and crossing fills; pass 50-year peak flow; minimize erosion; do not concentrate drainage on high risk sites.
Maintenance	Road maintenance and abandonment plans to be prepared w/in 5, 15 years for remediation; see also Riparian Areas (below)	4 classifications: Active, inactive, long-term inactive, permanently abandoned; various treatments based upon classification designed to minimize sediment input into streams	Maintenance and repair required on as-needed basis. Voluntary road assessment and repair effort by industrial forest owners under Oregon Plan underway.
Fish Passage	Road construction rules, road maintenance and abandonment schedules, compliance w/applicable state and federal fish passage rules (all fish, all life stages), see also Riparian Areas	New culverts and re-installations due to reconstruction or flood damage will provide for fish passage on streams designated as fish-bearing streams.	Met for new culverts but not assured for culverts in use before Sept. 1994, unless they are being replaced. Voluntary effort by industrial forest owners to inventory and upgrade passage problems underway.
Unstable Slopes	Uunstable slope mapping, individual application screening w/field verification, harvest restrictions on unstable slopes, expanded environmental review. See also incidental protection via expanded and improved riparian areas (below), rule improvement as needed via adaptive management	Potentially unstable slopes are identified by operator with field verification by state forest practices officer. Minimize impact of harvest of high risk sites on water resources. Avoid placing roads on high-risk sites unless no alternative. Harvest and yarding BMPs to reduce ground disturbance.	Potentially unstable slopes are defined in a general way (protocol not specified) and identified by operator for ODF verification. Minimize impact of harvest of high risk sites on water resources. Avoid placing roads on high-risk sites unless no alternative. Harvest and yarding BMPs to reduce ground disturbance.

Riparian Areas **General**	Riparian Areas measured horizontally from the edge of the bankfull channel or the edge of the channel migration zone (CMZ) whichever is greater.	Stream Protection Zone (SPZ) defined slope distance and average stream width measured between ordinary high water marks. CMZ not protected.	RMAs measured from annual high water level of the main channel or connected side-channels. RMAs along all streams are measured along the slope. No correction for steep sideslopes. CMZ not protected.
Westside			
Fish Streams	Shorelines of the State (Type S): no more than 30% volume removal every 10 years within 200 feet of shoreline. No management allowed inside channel migration zone (CMZ). Three zones: core, inner, outer. Core Zone (50 ft): no management Inner Zone: 2/3 SPTH buffers on streams <= 10 feet wide, managed with stand requirements; ¾ SPTH buffers on streams >10 feet wide with stand requirements. Hardwood conversion option under specific conditions. Outer Zone: SPTH buffer with 10-20 trees/acre	N/A	Two zones: Inner no-harvest, and riparian management area (RMA) Inner Zone (20 ft): no harvest; felling allowed for roads, yarding, temporary crossings, or stream improvement. Exception: hardwood conversion. RMA: 50-100 ft including no-harvest, depending on stream size (average flow). Retain 40 live conifers per 1000 ft for large streams, or 30 live conifers for medium. Also meet basal area requirements (vary by stream size) midway through 50-yr rotation. Exception: Basal area credit.
Non-Fish Streams	Perennial: 50-ft no-cut, plus sensitive sites; discontinuous with at least 50% buffer on length *Seasonal*: 30 ft equipment limitation	N/A	Medium and large N and D: 20-ft no harvest; felling allowed for roads, yarding, temporary crossings, or stream improvement. Retain 30 live conifers per 1000 ft for large streams, or 10 live conifers for medium. Meet basal area requirements (vary by stream size) midway through 50-yr rotation.

Riparian Areas Eastside - Fish Streams (continued)	Three additional zones: core, inner, outer. Core: (30 ft) no management Inner: 70 or 100 feet; management with stand requirements. Outer: SPTH buffer with 10, 15 or 20 trees/acre.	Class I: 75-ft SPZ. Management allowed within SPZs to minimum specified levels based upon stream width and tree diameters. Matrix used to determine # of leave trees per 1000 lineal feet within SPZs. Ground-based equipment not allowed in SPZs except at stream crossings.	Section Under Construction
Non-Fish Streams	Perennial: 50-ft managed buffer with uneven-aged management; discontinuous buffer with up to 300 ft. clearcut, but maximum of 30% length under even-aged management; plus 30-ft equipment limitation zone *Seasonal*: 30-ft equipment limitation zone *Note:* Small landowners exempt from new rules for <20-acre parcels for landowners who own less than 80 acres of forested land; DNR can add 15% of stand volume to current riparian buffers	Class II: 30-ft SPZ except where stream does not provide surface flow to Class I stream. Provide soil stabilization and water filtering effects by leaving undisturbed soils in widths sufficient to prevent washing of sediment. In no case shall this width be less than 5 feet.	

Wetlands Management Zones	Protection of Type A and B wetlands with 25- to 100-ft wide WMZs; minimum wetland size protected is 0.25 acre. Clearcut harvest allowed. Wetlands working group to make recommendations regarding protection via adaptive management. Generally 2:1 replacement ratio and no net loss of function Minimum mapping size to 3 acres for forested wetlands Classification System GIS update system Wetlands working group to revise system via adaptive management	Avoid conducting operations along bogs, swamps, wet meadows or other sources where the presence of water is indicated.	Stream associated wetlands > 8 acres, bogs (statewide), and "important" springs (eastside) protected by 50-100 ft RMA with 50% tree retention and qualitative soil/hydrological disturbance limits. Written plans shall describe how machine activity and roads will avoid adverse effects on water quality, hydrological functions and soil productivity.
Forest Chemicals	No chemicals in streams or core or inner zones. Variable width buffer depending on equipment and wind conditions New BMPs	Aerial application: pesticides not allowed within 100 ft of Class I streams, flowing Class II streams or other areas of open water. 50 ft buffer on aerial application of pelletized fertilizers. Ground application: 25 ft buffer for pesticides, 10 ft buffer for fertilizers.	No aircraft application within 60 ft of significant wetlands, aquatic areas of type F or D streams, or lakes. No manual application within 10 ft of significant wetlands, aquatic areas of type F or D streams, or lakes. Additional restrictions for fertilizers, fungicides, and non-biological insecticides.

Watershed Analysis	Mandatory for DNR as funding allow. Voluntary for landowners. Nine modules plus new ones. Improved hydrology and water quality modules. New cultural and restoration modules. No prescriptions for riparian, mass wasting, and surface erosion.	Not addressed directly. Addressed indirectly through CWE process (see Cumulative Effects, below)	Voluntary watershed assessment methods to enable watershed councils to select areas to restore or protect under Oregon Plan. No specific procedures or requirements for forest land analysis. Some landowners conduct their own analysis.
Ecological Interactions	Beaver control regulated separately by WDFW under trapping (severe restrictions on live trapping), dam removal/modification only w/ WDFW permit. Culvert blocking may be reduced via larger culverts, relocation of riparian adjacent roads and road abandonment activities	Give special consideration to preserving any critical wildlife or aquatic habitat.	Prior approval needed for beaver dam removal for dams farther than 25 feet from a culvert, unless dam threatens forests or plantations, or dam removal s part of control program approved by ODFW, or retaining dam would cause greater environmental harm.
Cumulative Effects	Basin hydrology addressed directly via rain on snow rule (where applicable), through harvest unit size, dispersion, and adjacency to young stands, and indirectly via road construction/drainage/ relocation/obliteration, by protecting and or re-establishing floodplain connectivity, and by protection of wetlands	Voluntary cumulative watershed effects (CWE) process. Process can be initiated by state, watershed advisory group, or landowner with >25% ownership. Development of site-specific BMPs approved by the state. Addresses only forestry activities. Does not include Federal lands.	Not assessed or regulated. Assumption that correctly implemented BMPs will avoid cumulative effects.

Variances	Alternate Plans allowed where alternate plan will provide at least equal protection as that provided by the rules. 20 acre RMZ exemption: Small land owner RMZ requirement is significantly reduced. RMZ widths of 29-115 feet per stream type/size. Minimal leave trees counts plus 15% of volume w/in RMZ. Salvage logging in RMZ in certain cases. Minimal width/frequency RMZ yarding corridors, stream crossings allowed. Large woody debris placement in lieu of standing leave trees in certain cases with WDFW approval. Hardwood conversion of portions of RMZ in certain instances.	Allowed if equivalent to BMPs.	Section Under Construction
Monitoring/ Adaptive Management	High priority for adaptive management establishedin rules. Cooperative Monitoring, Evaluation and Research Committee (CMER) formalized, independent scientific peer review process established. Dispute resolution process established. Conduct validation and effectiveness monitoring. Forest Practices Board responsible to refine rules as needed based on CMER results and other emerging science.	Potential revision of BMPs based upon site-specific information from voluntary CWE process.	ODF to conduct effectiveness monitoring of water protection rules, and chemical and petroleum product rules. Board of Forestry responsible for evaluating monitoring results and taking appropriate action.